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I. T. SEKI, CHEMICO-MINERALOGICAL INVESTIGATION OF THE WEATHERING PRODUCTS OF THE GRANITE OCCURRING NEAR MORIOKA.

II. T. SEKI AND I. JINNO, RESEARCHES ON THE NATURAL WEATHERING OF THE ABOVE GRANITE AND ARTIFICIAL LEACHING OF ITS WEATHERING PRODUCT.

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[I]

Chemico-Mineralogical Investigation of the Weathering Products of the Granite occurring near Morioka.

BY

Toyotaro Seki.

CHAPTER I.

INTRODUCTORY REMARKS.

In the eastern corner of the alluvial plain of Morioka lies a granitic hill called Tenjinyama near the western foot of the palæozoic mountain known as Iwayama. The granite is rather fine grained with grayish colour and gives the contact-metamorphism to the palæozoic slate in the west side of the mountain.

A. Mother Rock.

1. Mineralogical Constitution.

The granite consists essentially of the white felspars, grayish quartz, black biotite scales and oblong greenish black hornblende (Plate II, 1). The characteristics of these essential constituents under the microscope are as follows:—

The felspars consist of the ordinary plagioclase,

microcline and orthoclase, among which the first forms the greatest and the last the least part. The most of them exhibit zonal structure and are more or less decomposed, giving rise to turbidity in various degrees.

The *ordinary plagioclase* consists of several varieties between oligoclase and bytownite, among which the labradorite corresponding to $Ab_2 An_3$ most predominates. The interior of some crystals of plagioclase is replaced by the aggregate of the fibro-lamellar micaceous alteration products exhibiting the vivid interference-colour (Plate II, 2).

The *microcline* exhibits the characteristic cross-hatched structure and the *orthoclase* is found commonly twinned in the Karlsbad type.

The *quartz* is colourless transparent, with small apatites and minute fluid inclosures.

The *biotite* is yellowish brown and the *hornblende* exhibits a brownish green colour. They show distinct pleochroism and are at times altered into chlorite.

The bluish *apatite* is found in the essential ingredients of the granite, especially in quartz as fine needles and minute grains. The small crystals of the *zircon* are also rarely met with.

The result of the treatment of the rock powder with Toulet's solution of Sp. Gr. 2.8 has shown that the dark coloured ingredients amount to 25% of the whole rock. The biotite predominates among the dark ingredients, approaching perhaps 20% of the whole rock.

From the mineralogical constitution the granite undoubtedly belongs to the group of *grano-diorite*.

2. *Chemical Composition.*

The chemical analysis of the fresh granite gives the following result:—

Si O ₂	58.91	Ca O	6.39
Ti O ₂	0.08	Na ₂ O	4.46
Al ₂ O ₃	16.50	K ₂ O	2.04
Fe ₂ O ₃	6.83	P ₂ O ₅	0.44
Mn O	0.24	H ₂ O	1.35
Mg O	2.27		99.51

Compared with the typical analyses of the hornblende granites, the granite is slightly deficient in silica and considerably poor in potash, but remarkably rich in lime. In the fact that Al₂ O₃ > (Na₂ O + K₂ O), Na₂ O > K₂ O and Ca O > Mg O,⁽¹⁾ it approaches more to diorite than to granite.

B. *Weathering Products.*1. *Samples and Sampling.*

The two different kinds of the weathering products of the above-mentioned granite were taken as the materials for investigation. The *brown sample* was collected from the wall of a shallow pit in the west side of Tenjinyama, from where the granite was quarried (Plate I). The *gray one* was taken from the side of a new road through the hill, 10 metres below the top of the cutting. The latter is distinctly less weathered than the former retaining more or less the original structure of the mother rock.

Each sample was well mixed and sifted through

the sieve with the round holes one millimetre in diameter. The coarser residue was ground in a steel mortar till all passed through the sieve and mixed with the main part as was recommended by A. D. Hall.⁽²⁾

2. *Chemical Analysis.*

2 grams of the prepared sample were applied for the determination of the hygroscopic water and the loss on ignition.

10 grams were placed in Ellenmeyer's flask, covered with 100 c.c. of the concentrated hydrochloric acid and boiled on a sand bath for one hour, inserting the cork provided with a long glass condensing tube. The contents of the flask was then cooled, diluted and filtered. The washed residue was then digested with Lunge's solution (the aqueous solution containing 100 grams of crystallized sodium carbonate and 10 grams of caustic soda in a litre) to extract the amorphous silica set free by the acid.

2 grams of the dried residue after the treatment with Lunge's solution were put into a platinum dish, covered with 20 c.c. of concentrated sulphuric acid and heated cautiously on a sand bath till the thick white fume is given out as was recommended by H. Seger and E. Kramer.⁽³⁾ The contents of the dish was then cooled, diluted and decanted. The residue was digested for one hour on the addition of hydrochloric acid, diluted with water and filtered. The washed residue was treated with Lunge's solution as in the former case.

0.5 gram of the last residue was fused with sodium carbonate and 0.5 gram are decomposed with ammonium fluoride and sulphuric acid.

The analytical operations and determinations were carried out in the usual manner, the standard works of M. Dittlich⁽⁴⁾ and W. F. Hillebrand⁽⁵⁾ being frequently referred to.

3. *Microscopic Examination.*

The small quantities of the original samples and residues after the successive treatments with acids (and Lunge's solution) were sifted through the sieve with the very fine wire gauze and the coarser grains which remained on the latter were cautiously ground till all passed through. The aliquote portions of the mixed powders were mounted respectively with Canada balsam as is the case with the rock sections.

The preparations were examined under the microscope with ordinary and polarized light. In the special cases, the powders were mounted with the cedar oil, clove oil, creosote, cinnamon oil, bitter almond oil, carbon disulphide and their mixtures for the determination of the indices of refraction applying the well known methods of Fr. Becke⁽⁶⁾ and Schroeder van der Kolk.⁽⁷⁾

As the kaolinite has the index of refraction not far from that of Canada balsam, the microscopical image of the former grows very obscure, even almost invisible in that medium. This deficiency can be removed by imbedding the rock powder in glycerine-jelly for the examination of such a mineral substance.

4. *Tinction Experiment.*

The small portions of the original samples and residues after the successive treatments with acids were placed in very small porcelain dishes, covered with a moderately dark coloured aqueous solution of methylene-blue or acid-fuchsin and left to stand for ten minutes. The solids in the dishes were then washed cautiously by repeated decantations with water till the latter run colourless.

The coloured materials were examined under the microscope for the determination of the behaviours of the ingredients of different samples to these anilin dyes. The general behaviours of the most important soil ingredients to anilin dyes will be shortly mentioned.

The quartz, chalcedony and tridymite are quite indifferent to anilin dyes, even in the finest powder. The fresh well crystallized silicate minerals are also indifferent, but the decomposed parts and the minute granular, fine scaly or fibrous varieties of them absorb the basic anilin dyes in different degrees. The last case is probably due to the imperfect crystalloidal nature and the alteration, to which they are readily accessible.

The gelatinous silica and colloidal clays (*allophanoids*), when fresh and pure, absorb strongly the basic anilin dyes, becoming frequently almost opaque. Their strong basophilic characters are weakened by impurities, dessication, lapse of time etc.

The calcite, aragonite, dolomite and magnesites,

when fresh and pure, are indifferent to anilin dyes. The crystallized aluminium hydroxides—diaspor and gibbsite—are also indifferent.

The writer observed that the allophane and halloysite, which constitute the most important members of the allophanoid group take up the acid anilin dyes weakly, but rather distinctly. They behave sometimes almost indifferent, as many authors have remarked. The above mentioned allophanoids become almost indifferent to the alcoholic solution of the acid anilin dyes after ignition to faint redness for ten minutes.

The gelatinous aluminium hydroxide absorbs distinctly the acid anilin dyes. H. Behrens⁽⁸⁾ showed that its oxyphilic character is weakened by desiccation. The writer observed that the air-dried horny aluminium hydroxide increases its oxyphilic character after the weak ignition. The fact is probably due to the developement of porosity.

B. Hundeshagen⁽⁹⁾ and afterwards F. Dittler and C. Doelter⁽¹⁰⁾ have shown that the crystallized aluminium hydroxides which are completely indifferent to the acid anilin dyes become distinctly oxyphilic after ignition, especially in the case of gibbsite (=hydrargillite). The latter authors have also proved that the oxyphilic character of alumina appears more completely in the alcoholic medium.

From the preceeding facts, it is recommendable to use the alcoholic solution of acid anilin dyes as a means of discriminating amorphous aluminium hydroxide from above-mentioned allophanoids, and gibbsite from

kaolinite in the ignited samples. The tinction with the alcoholic solution will be carried out as in the case with the aqueous one and the washing should be done repeatedly with alcohol by decantation.

CHAPTER II.

MINERALOGICAL CONSTITUTION.

The weathering products of the granite consist of quartz, common plagioclase, alkali-felspars (microcline and orthoclase), yellow altered biotite, dirty green hornblende and the aggregates of the several kinds of decomposition products, the most of which are more or less coloured brown. The microscopical features of fresh and weathered minerals are given in the succeeding section.

A. Relatively Fresh Minerals.

1. *Quartz*.—It occurs as the more or less angular fragments, with numerous minute liquid cavities and small acicular and granular apatites. In the original samples, it is soiled with foreign decomposition products which are cleared away by hydrochloric acid.

2. *Common Plagioclase*.—Among the several varieties of plagioclase, the most of the basic ones were already decomposed and the remaining more acid varieties represent the main part of the common plagioclase. The plagioclase is mostly twinned in the albite type. The basic plagioclase altered almost entirely

into a gum-like mass is met with occasionally. I might designate this kind of decomposition as the "*gummy decomposition*." The basic plagioclase yields most easily to this kind of destruction.

3. *Alkali-Felspars*.—They consist of the microcline, with the characteristic cross-hatched structure and the orthoclase twinning frequently in the Karlsbad type. The former occurs more abundantly than the latter. The alkali-felspars have the tendency to pass into the lamellar aggregates resembling those of kaolinite. I might call this kind of decomposition the "*lamellar decomposition*." The alkali-felspars are resistant to the ordinary weathering and a relatively large amount of them remains unattacked after the treatment with sulphuric acid.

4. *Apatite and Zircon*.—The apatite occurs in fine needles and minute grains as the inclusions in biotite and colourless minerals, especially in quartz. The zircon is found very rarely in the free colourless well-formed crystals.

5. *Biotite*.—In the less weathered granite, the scales of the slightly altered greenish brown biotite are found. The biotite in our samples have undergone a farther decomposition resulting in a brownish yellow colouration. The surface of the altered biotite looks sometimes quite smooth, but it is more frequently dotted with numerous minute yellow granules and covered with the aggregates of fine yellow fibres. (Plate V). The granules and fibres have the comparatively high index of refraction and were proved to be *nontronite* ($H_4 Fe_2 Si_2 O_9$). The nontronitic fibres

are formed by the linear union of the yellow granules. The altered biotite takes up the methylene-blue in different degrees and that in which the decomposition is far advanced absorbs the colouring matter strongly and universally, showing that the scale is altered almost completely into the colloidal substance. The greatest part of the altered mica is decomposed by concentrated hydrochloric acid leaving a small amount of the white scaly residue, which is completely decomposed by hot sulphuric acid.

6. *Hornblende*.—It occurs mostly as the oblong dirty green fragments $\parallel c$ axis. The pleochroism is remarkably weakened owing to the partial decomposition. It tends at times to separate along the cleavages into the filaments consisting of the numerous green lamellae (*chlorite*) arranged vertically to the cleavages. The less altered hornblende resists the action of hydrochloric and sulphuric acids.

The residue after the treatment with sulphuric acid consists of quartz, alkali felspars, more acid plagioclase and hornblende, among which quartz most predominates.

B. Decomposition Products.

1. *Amorphous Aggregates*.

The numerous amorphous isotropic aggregates with the appearance of gum and roe are seen microscopically in the original samples. They are derived mainly from the more basic plagioclase and biotite as already explained.

The amorphous masses strongly absorb the methylene-blue (*strong basophilic*) and weakly acid-fuchsin (*weak oxyphilic*) from the aqueous solutions. No differential colouration takes place when the original samples are treated with the mixed aqueous solution of the above-mentioned two anilin dyes. After the ignition of the original samples to weak redness they become almost indifferant to the alcoholic solution of acid-fuchsin. The amorphous aggregates are completely decomposed by boiling hydrochloric acid.

From the form, structure and behaviours to acid and anilin dyes, it is highly probable that these aggregates consist mainly of the colloidal clay, viz. the *allophanoid*. The aggregates resemble closely to those found frequently in the volcanogenous loam, to which the author gave the general name "*argillitoids*."⁽¹⁾

The limonitic substance is found as the colouring matter of the amorphous aggregates and some altered biotites. The formation of limonitic substance from nontronite can be well traced.

2. Colourless Fibrous and Lamellar Aggregates.

In the original samples, the relatively small numbers of the lamellar and fibrous aggregates are found. They resist the action of hydrochloric acid and are completely decomposed by sulphuric acid. The aggregates can be divided morphologically into the following three groups:—

a. *Lamellar Aggregates*.—The most of them consist of very small scales (Plate IV, 3). The aggre-

gates with larger lamellae are also occasionally found (Plate III). The scales and lamellae are arranged in one row or in two to many rows giving rise to the vermicular, rouleau- and fan-shaped aggregates resembling those found in the typical porcelain clays. The detached scaly granules come frequently to sight, a few of which exhibits the rhombic or hexagonal outlines. The cleavage plates of orthoclase beginning in the lamellar decomposition are sometimes found (Plate IV, 2). The microcline tends to the formation of the fine scaly aggregates. From these observations, it is highly probable that the scaly and lamellar aggregates are mainly derived from the alkali-felspars.

b. *Fibrous Aggregates.*—They consist of the fibrous particles arranged nearly parallel or more or less confused and the most of them coincide morphologically with the micaceous decomposition products (paragonite?) found occationally in the plagioclase in the section of the less weathered granite (Plate II, 2).

c. *Mixed Aggregates.*—They occur as thin plates consisting of numerous fine scaly granules and fibrous particles and resemble closely to those of the white scaly residue after the treatment of the altered biotite with hydrochloric acid. The comparative examinations of the white micaceous scales, separated from a tertiary sand, under the microscope have revealed that they are the alteration products of biotite. The latter coincide with the mixed aggregates found in the weathering products of the granite of Morioka in form and origin (Plate IV, 1).

The indices of refraction of these three kinds of aggregates range from 1.54 to 1.56, the interference-colour never ascends the grayish white of the first order. The cleavage flakes behave as if isotropic. The low refraction and birefringency discriminate them from the light coloured mica (muscovite and paragonite). The optical sign of the elongated sides of lamellae is positive and the extinction angle fluctuates between 0° and 11°.

The larger lamellar aggregates take up the methylene-blue only in the interlamellar spaces and decomposed parts. The minute scaly granules absorb the basic dye rather distinctly. After weak ignition, all of them become almost indifferent to the alcoholic solution of acid-fuchsin. The presence of the *gibbsite* ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$) is by no means ascertained.

The aggregates and detached particles resist the action of hydrochloric acid, but are completely decomposed by boiling sulphuric acid.

These aggregates coincide thus with the kaolinite in the morphological and optical characteristics and in the behaviours to acids and anilin dyes. They resemble the "argillites" of F. Steinriede,⁽²⁾ who regards the latter as the kaolin-aggregates which are commonly found in soils. The chemical nature of the substances composing these aggregates will be further discussed in the succeeding chapters.

My observation on the formation of the kaolinitic substance from biotite confirms the hypothesis of K. D. Glinka⁽³⁾ based on the chemical analysis as will be explained in the next chapter under *Altered Biotite*.

3. *Green Lamellar Aggregates.*

They occur only in small amounts as the aggregates resembling those of kaolinite in shape and are derived from the hornblende as was already explained.

The pleochroism is distinct: blue green along the elongated sides of the lamellae and greenish yellow in the vertical direction. The interference colour exhibits the characteristic lavender blue. The optical sign of the elongated side is positive and the extinction of that direction is practically straight.

They are partially decomposed by hydrochloric acid and completely by sulphuric acid, as described by E. S. Dana in his mineralogy.⁽⁴⁾

From the appearance, optical characteristics and behaviours to the acids, it is clear that the aggregates are represented by a *chlorite* of the *pennin* group.

4. *Light Yellow Fibrous Aggregates.*

The aggregates consist of about ten to twenty greenish yellow fibres arranged nearly parallel or slightly radially. They are found scattered on the surface of the altered biotite (Plate V, 2) and occasionally as detached bundles (Plate V, 3). The formation of fibres from granules was already explained in this chapter under *Biotite* (Plate V, 1).

The pleochroism is weak: greenish along the fibres and light yellow in the vertical direction. On ignition they turn brown with a marked development of the pleochroism. The index of refraction lies between 1.61 and 1.62. The angle of extinction fluctuates

between 0° and 6°. The aggregates are decomposed completely by boiling hydrochloric acid and turn brown in with contact with the concentrated solution of caustic potash. They absorb the methylene-blue moderately and the acid-fuchsin faintly.

The optical characteristics and chemicalbe behaviours coincide with those of the *nontronite* ($H_4 Fe_2 Si_2 O_9$) which is sometimes incorrectly called "iron-kaolin." The nontronite in our samples resemble closely to that found in the weathered syenite of Lapland by A. Bergeat,⁽⁵⁾ who regards it as derived from hornblende, but not from biotite.

CHAPTER III.

CHEMICAL COMPOSITION.

A. Alterd Biotite.

The scales of the altered biotite were picked up from the weathered granite with much trouble. The smaller part of them was applied for the determination of the hygroscopic water and the loss on ignition, while the main part was boiled with concentrated hydrochloric acid for an hour. The washed residue was then treated with Lunge's solution. The altered biotite was thus almost completely decomposed, leaving a small quantity of quartz grains and white scaly particles. The decomposed part will, for the sake of brevity, be simply designated as the altered biotite, the percentage composition of which was found as follows:—

Si O ₂	36.48	Mg O	3.39
Ti O ₂	1.29	Ca O	0.30
Al ₂ O ₃	19.42	Na ₂ O	1.31
Fe ₂ O ₃	12.77	K ₂ O	4.90
Fe O	5.99	P ₂ O ₅	0.85
Mn O	0.53	H ₂ O	12.77

The composition lies approximately within the limits of nineteen Analyses of the *chloropals* (=nontronites) given by E. S. Dana⁽¹⁾ in his mineralogy as is shown in the following table:—

	Chloropals	Altered Biotite
Si O ₂	36.9—48.6	36.5
Al ₂ O ₃	0.0—26.0	19.4
Fe ₂ O ₃	11.0—39.5	12.8
Fe O	0.0— 6.1	6.0
Mg O	0.0— 2.6	3.4
Ca O	0.0— 3.4	0.3
Na ₂ O	0.0— 0.6	1.3
K ₂ O	0.0— 4.5	4.9
H ₂ O	7.0—13.0	12.8

The altered biotite may be regarded chemically as an impure variety of the chloropals, some of which correspond to the mixtures of nontronite and halloysite.

The majority of the altered biotite are more or less changed into the basophilic colloidal substances with the separation of nontronite, as has already been explained.

From the chemical point of view, the altered biotite corresponds roughly to the mixture of $\frac{1}{2}$ halloysite, $\frac{1}{4}$ nontronite and $\frac{1}{4}$ remainder consisting mainly

of ferrous oxide, alkali, magnesia, and a small quantity of silica. The ferrous iron will further give rise to the nontronite. When the weathering is far advanced, the altered biotite will change almost completely into the mixture of halloysite, nontronite, and limonite derived from the latter. The majority of the altered biotite in our samples have already undergone that change to rather considerable extent.

The *acid reaction* of halloysite and nontronite on litmus paper, was first observed by F. Cornu.⁽²⁾ The strong alkaline reaction, which characterizes the powdered fresh biotite was completely disappeared from our altered biotite which reacts quite neutrally.

E. Zschimmer⁽³⁾ demonstrated on the weathering of biotite that the potash is remarkably replaced by water with the diminution of iron. O. Dreibrodt⁽⁴⁾ has shown from his leaching experiment that ferrous oxide, magnesia and soda were considerably diminished, but the loss of potash was not remarkable. G. Daikuhara⁽⁵⁾ demonstrated that the powdered biotite begun to react acid after the treatment with carbonated water during a hundred days.

From these data and general facts on weathering, it is clear that the decomposition product of biotite begins to react acid, after considerable loss of alkaline bases. The acid reaction can be explained by the presence of halloysite and nontronite and the neutrality of our altered biotite by the remaining of enough alkaline bases owing to the incomplete weathering.

The formation of kaolinite from biotite remained long in question. Even H. Rosenbusch⁽⁶⁾ draws attention

only on the decolourization and chloritization. K. Glinka⁽⁷⁾ has recently shown the possibility of the formation of kaolinite out of biotite from the result of chemical analysis. The chemical compositions of fresh biotite and its decomposition product analysed by him, together with the percentage composition of the ideal kaolinite are shown in the following table:—

	Fresh Biotite	Lamellar Decomp. Product	Ideal Kaolinite
Si O ₂	36.6	43.4	46.6
Al ₂ O ₃	17.4	34.3	39.5
Fe ₂ O ₃	6.8	4.0	—
Fe O	15.4	—	—
Mg O	9.7	2.4	—
Ca O	0.3	—	—
Na ₂ O	0.9	0.3	—
K ₂ O	8.2	2.7	—
H ₂ O	2.4	12.8	13.9

The lamellar decomposition product of biotite coincides with the ideal kaolinite in the molecular ratios Al₂ O₃ : Si O₂ : H₂ O, viz. 1 : 2 : 2 and may be assumed chemically as an impure variety of kaolinite. The microscopical observation of the present writer on the kaolinization of biotite confirmed Glinka's hypothesis as already mentioned in the last chapter.

B. Weathering Products.

1. GENERAL RESULTS OF CHEMICAL ANALYSES.

The results of the chemical analyses of the above-mentioned brown and gray weathering products are shown in the next tables:

(a) *Chemical Analysis of the Brown Sample.*

Hygroscopic water.....	4.30
Loss on ignition	6.76
Mineral matter	88.95
	100.01

The mineral matter consists of the following constituents :—

Constituents	I Decomposed by H Cl	II Decomposed by H ₂ SO ₄	III Undecomp. Residue	I+II+III Total Sum
Si O ₂	20.89	3.19	31.21	55.29
Ti O ₂	0.07	.....	.....	0.07
Al ₂ O ₃	14.46	2.63	3.30	20.39
Fe ₂ O ₃	5.16	0.18	1.31	6.65
Fe O	1.00	.....	.....	1.00
Mn O	0.20	.....	0.14	0.34
Mg O	0.82	0.11	0.17	1.10
Ca O	0.18	Trace	0.76	0.94
Na ₂ O	0.25	0.24	0.59	1.08
K ₂ O	0.93	0.10	0.67	1.70
P ₂ O ₅	0.09	0.08	0.22	0.39
	44.05	6.53	38.37	88.95
Loss on Ignition	(5.83)	(0.85)	(0.08)	(6.76)

(b) *Chemical Analysis of the Gray Sample.*

Hygroscopic water.....	2.58
Loss on ignition.....	5.81
Mineral matter.....	92.51
	100.90

The mineral matter consists of the following constituents:—

Constituents	I Decomposed by HCl	II Decomposed by H ₂ SO ₄	III Undecomp. Residue	I+II+III Total Sum
SiO ₂	16.44	4.76	37.54	58.74
TiO ₂	0.05	.....	.....	0.05
Al ₂ O ₃	10.78	3.52	4.40	18.70
Fe ₂ O ₃	3.92	0.50	1.56	5.98
FeO	1.65	.....	.....	1.65
MnO	0.08	.....	0.14	0.22
MgO	1.26	0.19	0.25	1.70
CaO	0.30	Trace	0.02	1.32
Na ₂ O	0.26	0.60	0.61	1.47
K ₂ O	1.16	0.17	0.95	2.28
P ₂ O ₅	0.07	0.16	0.17	0.40
Loss on Ignition	35.97 (4.31)	9.90 (1.37)	46.64 (0.13)	92.51 (5.81)

2. CONSIDERATION UPON THE CHEMICAL COMPOSITION OF
THE PARTS DECOMPOSED SUCCESSIVELY BY ACIDS
AND THE FINAL RESIDUE.

(a) *The Part decomposed by Hydrochloric Acid.*

This part constitutes in the brown sample about 55% and in the gray one nearly 45% of the original materials. The molecular ratios of the important constituents of this part to alumina are as follows:—

	Brown Sample	Gray Sample
Si O ₂	2.45	2.58
Al ₂ O ₃	1.00	1.00
Fe ₂ O ₃	0.23	0.23
Fe O	0.10	0.21
Mg O	0.14	0.30
Ca O	0.02	0.05
Na ₂ O	0.03	0.04
K ₂ O	0.07	0.12
H ₂ O	2.29	2.27

The basic plagioclase has probably been decomposed by this acid, but the quantity must be very small, because this part contains only a small amount of soda and lime, which may partly be derived from other ingredients. The chlorite has partly been decomposed, but the quantity must be very small, because it is found only slightly in the samples. It is, therefore, clear that the mineral matter of this part is mainly derived from altered biotite, colloidal clay, nontronite, and limonitic substance.

Assuming that the ferric oxide belongs entirely to

the nontronite and deducing the molecular ratios of the silica and water to ferric oxide as in the form of nontronite from the corresponding ratios in the preceding table, the remainder gives the following ratios, which coincide nearly with those in the *halloysite* (hygroscopic water excluded).

In brown sample	$\text{Al}_2\text{O}_3 : \text{SiO}_2 : \text{H}_2\text{O} = 1 : 1.99 : 1.83$
In gray sample	$\text{Al}_2\text{O}_3 : \text{SiO}_2 : \text{H}_2\text{O} = 1 : 2.12 : 1.81$
In halloysite	$\text{Al}_2\text{O}_3 : \text{SiO}_2 : \text{H}_2\text{O} = 1 : 2 : 2$

It is, of course, impossible to determine exactly the amount of the altered mica in the part decomposed by hydrochloric acid. Assuming that the ferrous oxide and potash in this part are entirely derived from the altered biotite, the calculations were made to estimate the amount of the latter from the quantity of each of those two constituents giving the following results:—

	Calculated from		Average
	Ferrous oxide	Potash	
In brown sample ...	16.7%	19.0%	18%
In gray sample	27.5%	23.4%	25%

The amounts of the altered biotite thus found fluctuate between $\frac{1}{3}$ and $\frac{1}{2}$ of the part decomposed by hydrochloric acid. The greater contents of the gray sample in the altered biotite can easily be perceived macroscopically.

The remainder of the part decomposed by hydrochloric acid, from which the altered biotite is supposed to be removed can be assumed to consist mainly of halloysite. To find the amount of *halloysite* ($\text{H}_4\text{Al}_2\text{Si}_2\text{O}_9 + \text{H}_2\text{O}$) from the quantity of aluminia, it is necessary to

multiply the latter by 2.71. The calculations based on this principle were carried out as follows:—

In brown sample	In gray sample
$14.46 \times 2.71 = 39.2$	$10.78 \times 2.71 = 29.9$
$19.42 \times 0.18 \times 2.71 = 9.5$	$19.42 \times 0.25 \times 2.71 = 13.2$
Halloysite 29.7	Halloysite 16.7

The *halloysite* in the remainder thus found corresponds to 30% and 17% of the original materials of these two samples respectively. The altered biotite which corresponds to the mixture of nontronite and halloysite in chemical composition, contains undoubtedly the latter decomposition product in not inconsiderable degree. It is, therefore, highly probable that the amounts of *halloysite* in the original materials far exceed 30% in the case of the brown sample and come at least to 20% in the gray one.

(b) *The Part decomposed by Sulphuric Acid.*

This part forms in the brown sample 7.5% and in the gray one 11% of the original materials. The molecular ratios of the important constituents to alumina in this part of our samples and those calculated from the analysis of the lamellar decomposition product of biotite given by Glinka are shown in the following table:—

	Brown Sample	Gray Sample	Decomposed Biotite
Si O ₂	2.05	2.29	2.14
Al ₂ O ₃	1.00	1.00	1.00
Fe ₂ O ₃	0.04	0.09	0.07
Mg O	0.10	0.14	0.18

Na ₂ O	0.15	0.25	0.02
K ₂ O	0.04	0.05	0.08
H ₂ O	1.83	2.21	2.11

With the exception of the amount of soda, the compositions of the decomposed parts in our samples resemble that of the lamellar weathering product of biotite which was supposed to be the kaolinite by Glinka.

That part of the chlorite, which escaped the action of hydrochloric acid was completely decomposed by sulphuric acid. The contents of the chlorite in this part were calculated, under the assumption that it is represented by the *pennin* corresponding to Sp_2At_3 , giving 0.6% for the brown sample and 1.36% for the gray one. The amounts of the constituents of the chlorite were subtracted from the corresponding quantities of those in the parts of our samples decomposed by sulphuric acid and the molecular ratios were calculated from the remainders. The ratios thus found and those for the ideal kaolinite are shown in the following table:—

	Brown Sample	Gray Sample	Ideal Kaolinite
Si O ₂	2.00	2.19	2.00
Al ₂ O ₃	1.00	1.00	1.00
Na ₂ O	0.16	0.29	.....
K ₂ O	0.04	0.05	0.34
H ₂ O	1.74	2.06	2.00

The molecular ratios Al₂ O₃ : Si O₂ : H₂O coincide very nearly to those of the ideal kaolinite and on the other hand, the ratios Al₂ O₃ : Si O₂ : (Na, K)₂ O resem-

ble those of *paragonite*, the most common varieties of which are represented chemically by the formula (Na, K) $H_2 Al_2 Si_3 O_{12}$.

There is no doubt that the colourless fibrous and lamellar aggregates which represent almost entirely the part not attacked by concentrated hydrochloric acid, but completely decomposed by boiling sulphuric acid exhibit various stages between *kaolinite* and *paragonite*. The possibility of the common occurrence of such decomposition products will be more fully discussed in the next chapter under the head of the *Kaolinitoid*.

(c) *Final Residue.*

The final parts constitute in the brown sample 38.5% and in the gray one 47% of the original materials. The *quartz* occupies more than half of the residue, the *hornblende* will never exceed 10% of this part and the remainder is represented by the minerals of *felspathic group* (nearly 30%).

Assuming that the total amounts of potash and soda derived from the alkali-felspars and the lime is entirely from both apatite and lime-felspar (anorthite), the calculations were made for the estimation of the ideal amounts of those four mineral ingredients giving the following results:—

	Brown Sample	Gray Sample
Apatite	0.5	0.4
Orthoclasic substance ...	4.0	5.6
Albitic substance	5.0	5.2
Anorthitic substance.....	2.5	4.1
	11.5	14.9

The actual quantity of the anorthitic substance will be smaller than that here given, because some lime must belong to hornblende. The greater part of the orthoclasic substance in association with a small amount of the albitic one constitutes the *microcline* and a smaller part of it exists free as the *orthoclase*.

The remaining albitic substance, together with the anorthitic one forms the *plagioclase*, among which the more acidic varieties predominate. The *apatite* is found as the inclusions in quartz and felspars as already mentioned.

CHAPTER IV.

SUMMARY AND CONCLUSION.

A. Loss and Gain of Substances by Weathering.

The chemical compositions of the fresh granite and its decomposition products are shown in the following table:—

	Fresh Granite	Decomposition Products	
		Gray Sample	Brown Sample
Si O ₂	58.91	58.74	55.29
Al ₂ O ₃	16.50	18.70	20.39
Fe ₂ O ₃	6.83	7.81	7.76
Mg O	2.27	1.70	1.10
Ca O	6.39	1.32	0.94
Na ₂ O	4.46	1.47	1.08
K ₂ O	2.04	2.28	1.70

P ₂ O ₅	0.44	0.40	0.39
H ₂ O	1.35	8.39	11.06

Assuming that no loss has taken place in alumina, the calculations were made to find the loss and gain of the important constituents by weathering, giving the following results:—

	Gray Sample	Brown Sample
	%	%
SiO ₂	— 12.0	— 24.0
Al ₂ O ₃	± 0.0	± 0.0
Fe ₂ O ₃	+ 0.9	— 8.0
MgO	— 33.9	— 60.8
CaO	— 81.8	— 88.1
Na ₂ O	— 70.9	— 80.4
K ₂ O	— 1.4	— 32.6
P ₂ O ₅	— 19.8	— 28.3
H ₂ O	+448.5	+563.1

The water increases very considerably and the alkaline bases, especially the lime and soda, decrease in great extent. These facts show clearly that the hydration and leaching of alkaline bases take place very vigorously by weathering under our climatic conditions.

The magnesia diminishes gradually, but rather considerably and the loss is undoubtedly due to the decomposition of biotite. The rapid removal of lime and soda corresponds to the fact of the easy accessibility of the basic plagioclase to atmospheric agencies. The gradual and inconsiderable decrease of potash can be explained by the resistance of alkali felspars to the action of

weathering and the strong retention of potash by the amorphous decomposition products, especially colloidal clays.

B. Most Important Decomposition Products.

(1) *Allophanoid.*

The amorphous aggregates which are completely decomposed by hydrochloric acid and represent the greater part of the decomposition products, resemble those of allophanoids in form, structure, isotropy, and behaviours to acids and anilin dyes. In the present state of physical and chemical manipulation, it is, of course, impossible to isolate the colloidal ingredients of soil and examine them exactly, but it is highly probable that more than half of the part decomposed by hydrochloric acid corresponds to the *halloysite* ($H_4 Al_2 Si_2 O_9 + H_2 O$) in chemical composition as was explained in the chapter III.

From these points, the present writer assumes that the strong basophilic amorphous aggregates decomposed by hydrochloric acid are mainly constituted of an allophanoid corresponding to *halloysite*. The deficiency of our samples in plasticity, when wet, is explained by the presence of the halloysite, which is generally hardly plastic,⁽¹⁾ as the chief weathering product.

The absence of the acid reaction which characterizes the pure halloysite is probably due to the presence of the absorbed alkaline bases and of the fresh minerals which react alkaline, as hornblende and felspar. The action of the powdered orthoclase, anorthite and fresh

granite to compensate the acid reaction of allophanoids was experimentally ascertained by the present author.⁽²⁾

There is no doubt, from the preceding data, that in our samples of the weathered granite, the leaching is not far enough advanced, so as to exhibit an acid reaction. It can surely be expected that they will begin to react acid by the farther action of weathering, as was proved by the artificial leaching experiments carried out by the author in conjunction with I. Jinno. The results will be fully described in the next essay.

(2) *Nontronite.*

It occurs in a relatively small amount as the aggregates of the fine yellowish fibres arranged nearly parallel or somewhat radially. It is found scattered on the surface of altered biotite and as the detached bundles. The fibres are formed by the union of the minute yellow granules appeared on the surface of altered biotite (Plate V).

The aggregates are completely decomposed by hydrochloric acid and absorb the methylene-blue rather distinctly. Nontronite may be regarded as a ferruginous representative of kaolinite from its chemical composition and is often called the "iron-kaolin," but it differs from kaolinite in many important characteristics.

H. Stremme⁽³⁾ pointed out that the nontronite approach more to allophanoids than to kaolinite in its behaviour to hydrochloric acid and in the mode of its formation. The present writer recognizes moreover the marked difference between these two substances in the

points that the nontronite is very unstable compound and its composition fluctuate to certain extent as is the case with allophanoids. The nontronite in our sample may be regarded as a *pseudo-colloidal* substance.

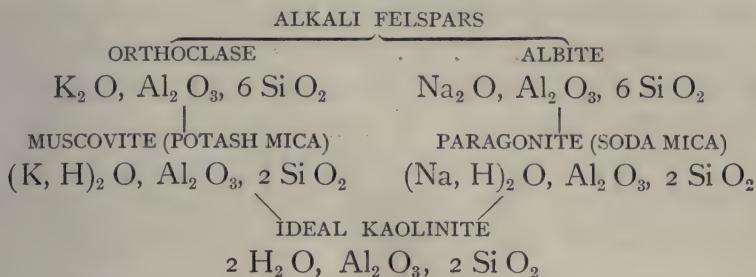
(3) *Kaolinitoid.*

The almost colourless fibro-lamellar aggregates, which are found in the residue after the treatment with hydrochloric acid, and are completely decomposed by sulphuric acid, resemble the kaolinite in form, structure, refraction and birefringence. The two latter characteristics discriminate them from the light coloured mica (muscovite and paragonite).

The chemical compositions of these parts which are decomposed by sulphuric acid resemble kaolinite in the molecular ratios $\text{Al}_2\text{O}_3 : \text{SiO}_2 : \text{H}_2\text{O}$ and on the other hand approach paragonite in the ratios $\text{Al}_2\text{O}_3 : \text{SiO}_2 : (\text{Na}, \text{K})_2\text{O}$. There is no doubt that the substance constituting the majority of the above-mentioned aggregates possess the characters of both kaolinite and paragonite in the chemical point of view.

The great many modern mineralogists, for example M. Bauer,⁽⁴⁾ accept the existence of every possible intermediate decomposition products between felspar and kaolinite in the weathering of the former. V. Selle⁽⁵⁾ and G. Hickling⁽⁶⁾ published their views on the formation of kaolinite from the secondary sericitic mica derived from the alkali-felspars by weathering. One will readily recognize the possibility of these cases, if he compares the chemical compositions of the alkali

feldspars, light coloured mica and kaolinite, as are shown in the following scheme:—



Tschermak regarded the biotite as the isomorphic mixture of muscovite substance and olivine substance. If we grant his hypothesis, we can easily imagine that the kaolinite is possible to be derived from the *muscovite component* of biotite. But this question remained long undissolved. Glinka's chemical assumption and my microscopical observation agreed to prove this possibility as already explained.

The kaolinitic substances in our samples, which are derived from alkali-feldspars, biotite and secondary light coloured mica (paragonite?) exhibit the optical characters of kaolinite and the chemical compositions between ideal kaolinite and paragonite. There is no doubt of the frequent occurrence of such impure and imperfect kaolinitic substances in nature. *I might designate such decomposition products as the "Kaolinitoids" for the sake of convenience.*

Some authors maintain that the kaolinite crystallizes out in the colloidal weathering product having the same chemical composition as the former in the lapse of a long time (often geological). The present

writer admits the frequent occurrence of such a colloidal substance which is analogous to kaolinite plus water (halloysite), but does not believe that it is able to remain so long unchanged. F. W. Clarke⁽⁷⁾ stated also that the halloysite is an unstable silicate of alumina [more probably *aluminosilicic acid*] and is not the end product.

The aggregates of kaolinitoids in our samples occur always apart from the colloidal masses and the crystals of the former are not detected in the latter. It is consequently highly probable that the kaolinitoids are, at least in our cases, not the substance which is crystallized in the colloidal ground mass.

H. Stremme⁽⁸⁾ classifies the argillaceous matter produced by weathering into two groups: "*Feldspatreste*" and "*Allophanoide*." The former is the decomposition products representing every stage between the felspar and kaolinite, without the addition of foreign substances and differing from the latter, being practically insoluble in hydrochloric acid. *The kaolinitoids in our samples coincide partly with the "Feldspatreste" of Stremme and partly with the "Glimmerreste" as I might say.*

C. Kinds of Weathering and their Results.

Van Hise⁽⁹⁾ divides the upper portion of the lithosphere into two zones: *A zone of weathering and a zone of cementation*. In the former the chemical and mechanical action of the ordinary weathering goes rapidly and violently on and in the latter the deposition of mineral matter takes place causing the induration of rocks.

The boundary between those two zones is pointed out as the permanent level of ground water.

It is however questionable, whether directly under that level the deposition soon takes place, because the water there does not usually contain so much mineral matter as to separate it out. F. W. Clarke⁽¹⁰⁾ pertinently suggested in addition to Van Hise's statement as follows : "Nor can the belt and zone be rigorously delimitated, for they shade into and even interpenetrate one another."

F. Cornu⁽¹¹⁾ who has contributed not a little to the application of the chemistry of colloids to the study of minerals and soils, explained clearly the distinction between the *surface* and *secular* weathering. The former corresponds naturally to the *ordinary weathering* and latter may also be called the *deep-seated weathering*. Of the secular weathering, Cornu gives the following interesting explanations :—

"The atmospheric water, which gave out the greater part of its carbon dioxide and oxygen in the upper layer and sank down through the capillaries in the rock, acts here continuously for a long time giving rise to the crystalloid with an analogous composition as the gel produced by the surface weathering; *in all cases, where the constant circumstances (pressure, temperature etc.) prevail, the crystalloids are produced and where these conditions change rapidly, the gels are formed.*"

P. P. von Weimarn⁽¹²⁾ concluded, from the consideration of a great number of observations by himself and other investigators, that *the colloidal state is the general character of matter*, the crystallizable substances being

able to be transformed into the colloidal state and the colloidal ones being able to be obtained as distinct crystals.

R. Brauns⁽¹³⁾ stated, about the formation of the pseudomorphs, that they are produced only in the cases, where the alteration takes place gradually, not accompanied by the remarkable change of volume. Van Hise suggested that the minerals of the upper zone are formed with increase of volume and those of the lower zone by contraction.

J. V. Elsden⁽¹⁴⁾ stated for the difference of the chemical reactions at the surface and underground as follows: "It is probable that many chemical reactions which take place upon the surface either cease or are reversed at a great depth, especially when considerable volume change results. Thus hydration below the surface may be partially or entirely checked by pressure, owing to the resistance to expansion."

The present writer concludes, from the opinions of these authors, as well as from his own observations, that the surface weathering is not favorable to the formation of such pseudomorphous crystalloids, as secondary mica, kaolinite etc., but gives a suitable circumstance to the production of colloidal substances.

It is a well known fact that the kaolinite represents usually the decomposition product of the alkali-felspars. The question whether the kaolinite be derived from the anorthite has long been left unsettled. It was decided recently that the lime-felspar tends mainly to the formation of the allophanoids as zeolites and felspathoids.

H. Rosenbusch⁽¹⁵⁾ pointed out that the formation of

colourless mica and kaolinite is observed frequently in the orthoclase and acid plagioclases (albite to andesine), but seldom met with in the more basic plagioclases. The observations of the present writer concur also with this view. Thus there is no doubt that the more resistant acidic felspars possess the great tendency to the formation of kaolinite than the basic ones, which are readily accessible to the weathering, giving rise to the colloidal clays. In short, the kind of decomposition product of felspar depends not only upon the physical and chemical nature of the latter, but also upon the kind and activity of the weathering. In the case of biotite, the decomposition product depends probably upon the kind of the weathering as in the case with felspars.

The presence of both *kaolinitoid* and *colloidal clay* analogous to the former in our samples is clearly explained by Cornu's hypothesis as the result of the successive actions of the *secular* and *surface* weathering. When the deep buried rock mass, which affected the action of secular weathering in certain degree has been exposed to atmospheric actions by the upheaval of ground, removal of overlaying weathering products etc., the surface weathering goes on rapidly to attack rock ingredients resulting in the formation of colloidal substances. The decomposition products in such cases may, of course, contain both crystalloidal and colloidal substances. The abundance of the gray sample in the *kaolinitoid*, notwithstanding the ordinary weathering having less advanced than the brown one is undoubtedly due to the fact that the former has long remained deep underground, being favorable to the formation of the crystalloids.

F. Cornu⁽¹⁶⁾ published his note-worthy views on the influence of climate upon colloid-formation and stated that the circumstances which promote the ordinary weathering accelerate also the production of gels. *The richness of our samples in colloidal substances is mainly due to the climatic condition of our district in concord with Cornu's view.*

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(THE END)

[II]

Researches on the Natural Weathering of the Granite and Artificial Leaching of its Weathering Product.

BY

Toyotaro Seki

AND

Ikuma Jinno.

The samples were taken from the same pit where the brown sample mentioned in the preceding essay was found. They consist of the following three kinds:—

1. Fresh granite (granodiorite).
2. Fragile half-weathered crust of the former.
3. Loose weathering product.

The last named is light yellowish brown in colour and occupies a little higher level than that of the brown sample.

The bulk analysis and dyeing experiment were carried on in our laboratory and the results were reported on a periodical of the college-associates (No. 24, 1914). From the comparison of these data and the reactions of samples on litmus paper, it was presumed that the loose weathering product, which exhibits now the neutral reaction will begin to react acid on the

slight removal of alkaline bases by the atmospheric water.

G. Daikuhara treated the powdered granite with the carbonated water during 12 weeks and found that the considerable quantities of magnesia, lime, ferrous oxide and soda were dissolved out. He has moreover observed in another experiment that the granite powder has shown weak acid reaction after the treatment with carbonated water during a hundred days (The Bulletin of the Central Agricultural Experiment Station of Japan, Vol. II, No. 1, 1914).

From these two facts, it will easily be seen that there exists a close relation between the loss of alkaline bases and the appearance of acid reaction. To solve this question experimentally, we have carried out the artificial leaching in the following manner:—

20 grams of the loose weathering product was placed into a bottle, 300 c.c. distilled water was added and the carbon dioxide gas was passed half an hour in moderately rapid current. The closed bottle was shaken with the rotating apparatus for 8 hours, allowed to stand upright till the next morning, when the supernatant clear portion of the fluid was syphoned off and the distilled water was added to the former level. The conduction of gas, shaking of bottle and subsequent treatment were carried out during ten days in the same way. The solid in the bottle was then transferred in a filter paper and washed thoroughly with distilled water. We have found that the washed residue exhibits a rather weak, but distinct permanent acid reaction on litmus paper.

The results of the bulk analysis of the loose weath-

ered sample and the residue after artificial leaching, together with those of the fresh granite and half-weathered crust are shown in the following table:—

	Earthy Weathering Product			
	Fresh Granite	Half Weathered Crust	Natural	Treated with CO ₂
Si O ₂	58.91	60.60	55.77	55.02
Ti O ₂	0.08	0.09	0.08	0.07
Al ₂ O ₃	16.50	16.50	19.33	18.49
Fe ₂ O ₃	6.83	7.63	8.37	9.11
Mn O	0.24	0.24	0.22	0.30
Mg O	2.27	2.43	1.87	1.63
Ca O	6.39	15.16	4.73	0.61
Na ₂ O	4.46	2.81	1.45	1.21
K ₂ O	2.04	1.48	0.44	0.40
P ₂ O ₅	0.44	0.34	0.48	0.36
H ₂ O above 100°	0.97	1.35	2.39	9.37
H ₂ O at 100°	0.38	1.21	3.60	3.68
	99.51	100.45	100.46	100.25

From these results, the molecular ratios of more important chemical ingredients to 1 Mol. Al₂O₃ were calculated giving the following results:—

	Earthy Weathering Product			
	Fresh Granite	Half Weathered Crust	Natural	Treated with CO ₂
Si O ₂	6.05	6.22	4.89	5.04
Al ₂ O ₃	1.00	1.00	1.00	1.00
Fe ₂ O ₃	0.26	0.30	0.28	0.32
Mg O	0.35	0.37	0.25	0.22
Ca O	0.71	1.64	0.52	0.06
Na ₂ O	0.45	0.28	1.27	0.11
K ₂ O	0.13	0.10	0.02	0.02
H ₂ O	0.46	1.24	3.46	4.01

The data of above two tables show us clearly that the large amounts of alkaline bases are carried away by the natural weathering and that they are also removed by the artifical leaching in a small extent.

The fine earthy part (<0.5 mm in Dia.) of the fully weathered soil was treated with the carbonated water in the exactly same manner and duration. The original sample and that after the treatment were extracted with boiling concentric hydrochloric acid and the decomposed constituents were determined giving the following results :—

	Natural	Treated with CO_2
Si O_2	22.25	22.59
Ti O_2	0.07	0.11
Al_2O_3	13.89	15.17
Fe_2O_3	7.65	7.68
Mn O	0.18	0.36
Mg O	1.55	1.33
Ca O	0.47	0.19
Na_2O	0.98	3.36
K_2O	0.36	0.31
P_2O_5	0.17	0.14
H_2O above 100°	10.10	9.90
H_2O at 100°	3.49	4.27
Undecomposed	39.14	36.98
	100.30	99.97

From the above data, the molecular ratios of more important constituents to 1 Mol. Al_2O_3 were calculated giving the following results :—

	Natural	Treated with CO ₂
Si O ₂	2.72	2.52
Al ₂ O ₃	1.00	1.00
Fe ₂ O ₃	0.35	0.32
Mg O	0.28	0.22
Ca O	0.06	0.02
Na ₂ O	0.12	0.10
K ₂ O	0.03	0.02
H ₂ O	5.54	5.30

The results obtained with the fine earth coincide with those of the preceding experiments in regard to the loss of alkalline bases by the artificial leaching. The slight decrease in water after the treatment with carbonated water are probably caused by the unavoidable error in the analytical process.

1 gram of the powder of fresh granite and half-weathered crust, earthy weathering product and the residue after treatment with carbonated water was placed in the small flask and 100 c.c. dilute aqueous solution of methylene-blue (containing 5 cg of the latter) was added. The bottle was at first shaken very cautiously and then left to stand for 24 hours. The supernatant fluid is sucked out with a pipette, the content of the colouring matter was determined colorimetrically and the quantity of methylene blue absorbed by each sample was calculated giving the following results:—

	cg
Fresh granite	0.35
Half-weathered crust	0.67
Fully weathered sample	2.48
	natural
	treated with CO ₂
	2.54

Fine earth of the latter	natural	2.87
	treated with CO ₂	2.91

From the results, it is clear that the absorptive power for the methylene-blue (a basic anilin dye) increases considerably as the weathering advances and that the results of artificial leaching show the same tendency in a less degree.

The most important data given by the preceding experiments are summarized in the following table:—

Various Samples	Alk. Bases		Water		Met. Blue Absorb- ed (cg)	Reaction on Litmus Paper
	%	Mol.	%	Mol.		
Fresh Granite	15.16	1.64	1.35	0.46	0.35	Dist. Alk.
Half Weath. Crust	11.45	1.27	3.60	1.24	0.67	Weak Alk.
Fully Weath. Sample	Natural.....	4.43	0.46	11.78	3.46	2.48
	Treatd. w. CO ₂	3.85	0.41	13.05	4.01	2.54
Fine Earth of the Latter	Natural.....	3.36*	0.49	13.59	5.54	2.87
	Treatd. w. CO ₂	2.77*	0.36	14.17	5.30	2.91

* Decomposed by conc. HCl.

Conclusions.

(1) The increase of water is undoubtedly due to the formation of colloidal and pseudo-colloidal substances as halloysite, limonite and nontronite, although it may partly be caused by the formation of such crystalloids as kaolinitoid and chlorite.

(2) The absorption of methylene-blue is chiefly carried on by the colloid (halloysite) and pseudo-colloid

(nontronite), especially the former as was explained in the preceding essay by one of the authors.

(3) The increase of the absorptive power for the basic dye (methylene-blue) in the weathering products shows undoubtedly the progressive developement of the basophilic colloids and pseudo-colloid, especially halloysite and nontronite.

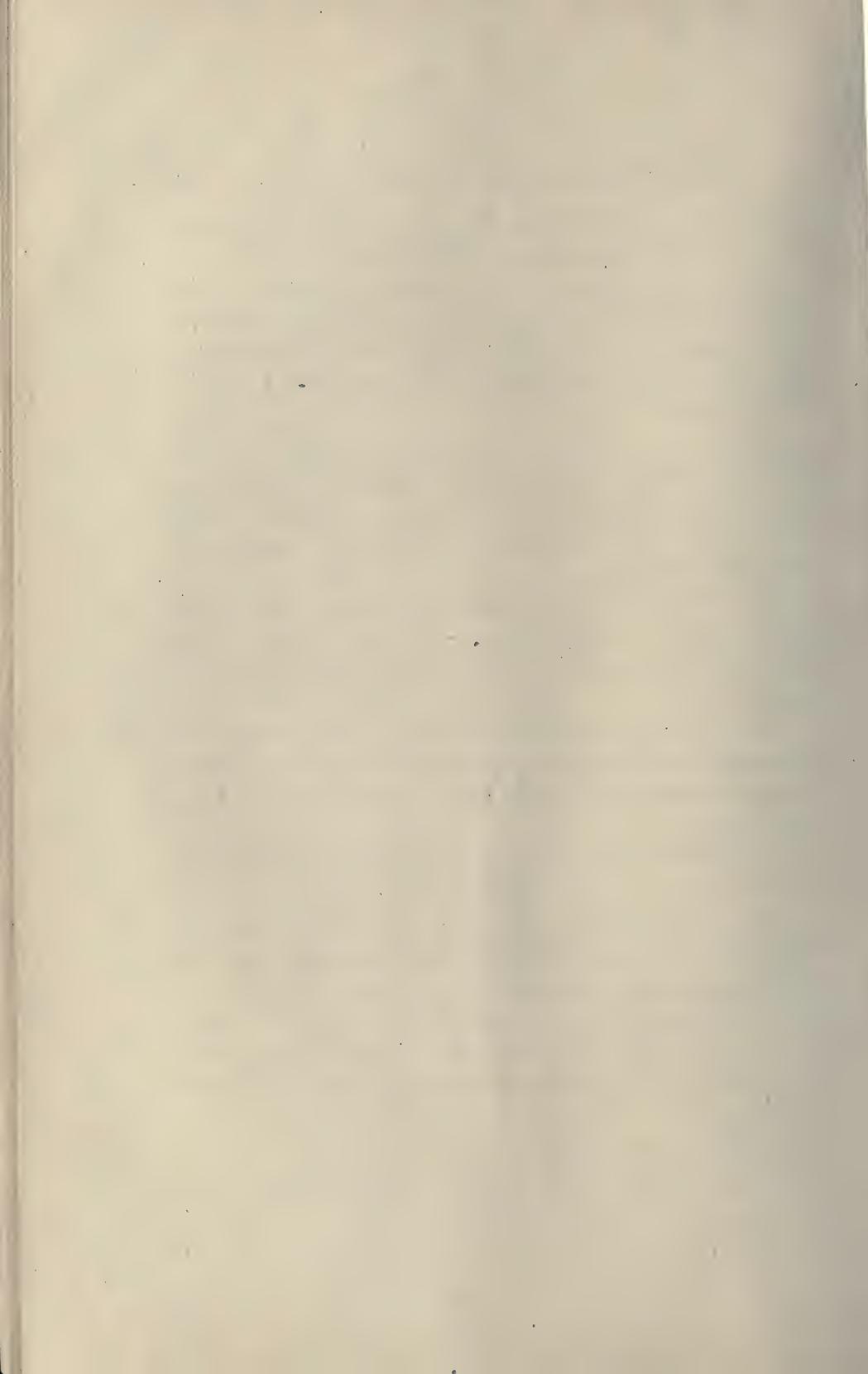
(4) The increase of the absorptive power after the artificial leaching can be explained by the removal of the alkalline bases from the colloidal substances and perhaps the new formation of a small quantity of basophilic colloids.

(5) The loss of alkalline bases after the artificial leaching takes mainly place in the part of fine earth and probably in the colloidal and pseudo-colloidal portions.

(6) The full-weathered sample reacts neutral in the natural state, but its neutrality is soon destroyed by a slight removal of alkaline bases as one of the authors presumed.

(7) The main cause of the acid reaction of the residue treated with carbonated water can be explained as the appearance of the characteristic behaviours of halloysite and nontronite by the removal of the adsorbed alkaline bases from them.

(THE END.)



PLATES

TO

THE CHEMICO-MINERALOGICAL
INVESTIGATION

OF

THE WEATHERING PRODUCTS OF THE GRANITE
OCCURING NEAR MORIOKA.

BY

TOYOTARO SEKI.

PLATE I.



THE INTERIOR OF A SMALL PIT WHENCE OUR SAMPLES WERE TAKEN.

- 1. FRESH GRANITE. 2. HALF-WEATHERED CRUST.
- 3. FULLY WEATHERED PORTION.

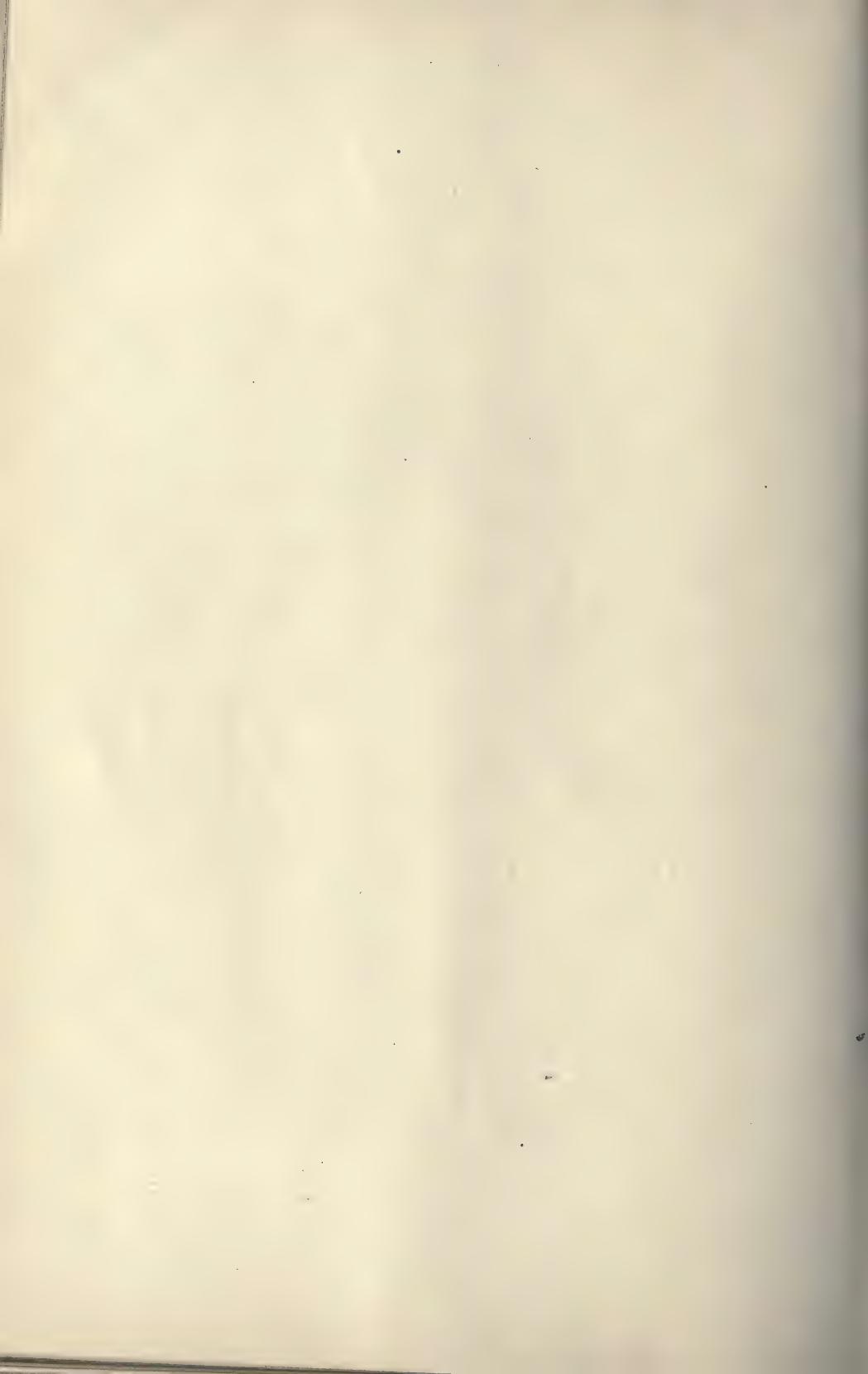
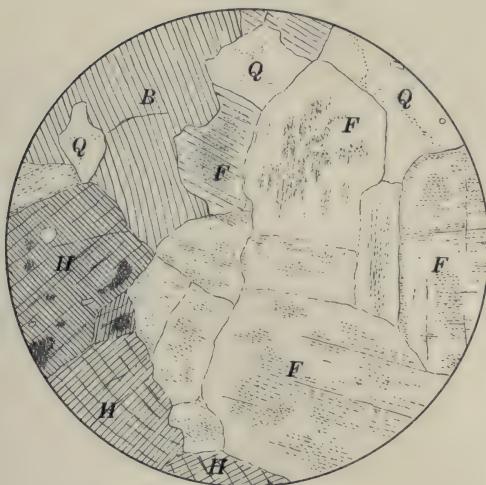


PLATE II.



1. HORNBLENDE GRANITE (GRANODIORITE).

F. FELSPAR (CHIEFLY PLAGIOLASE). Q. QUARTZ.
B. BIOTITE. H. HORNBLENDE.

× 18.



2. PLAGIOLASE WITH THE MICACEOUS DECOMPOSITION PRODUCT.

P. PLAGIOLASE. Q. QUARTZ. A. APATITE.
M. MICACEOUS DECOMPOSITION PRODUCT.

× 100.

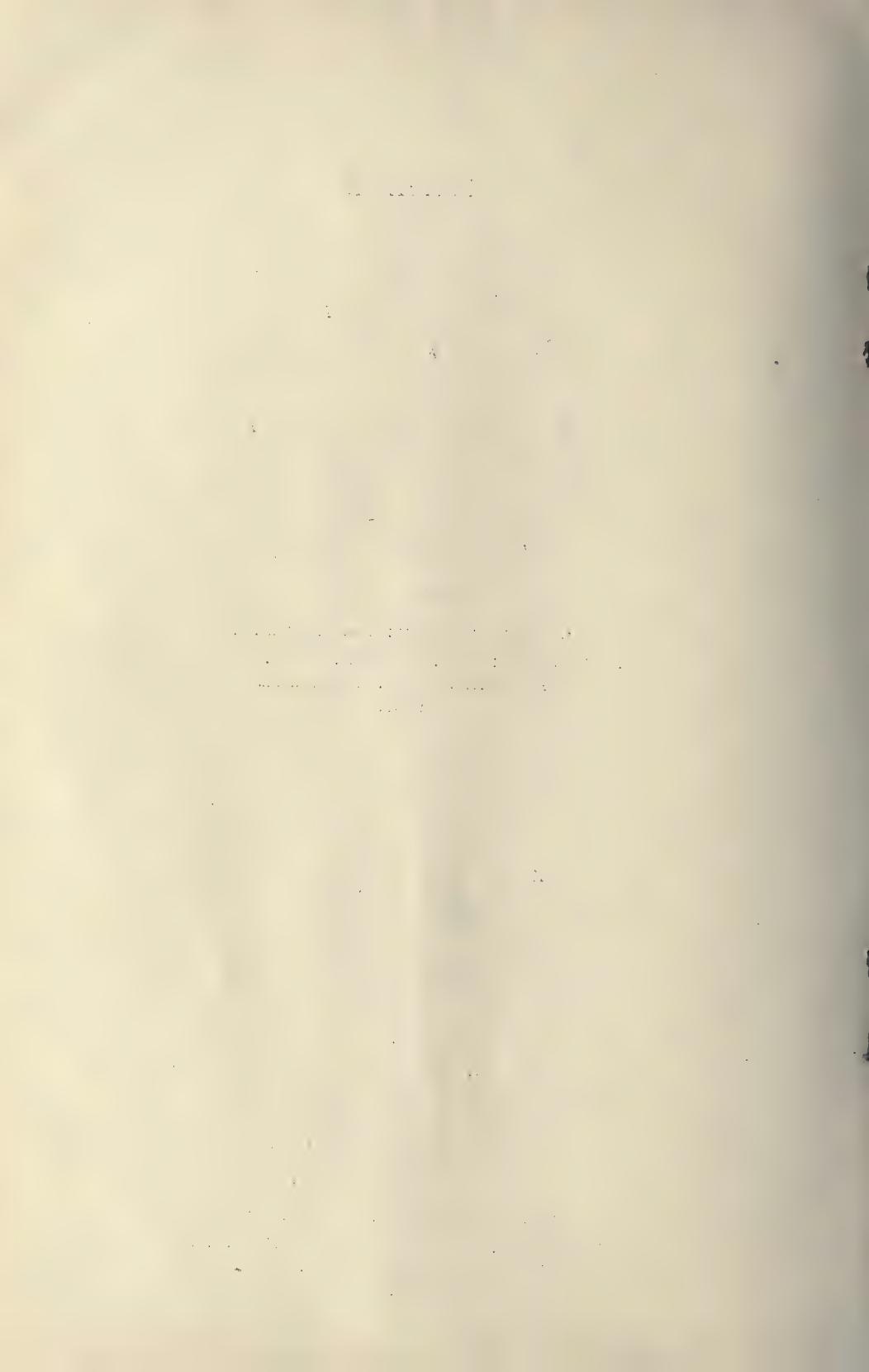
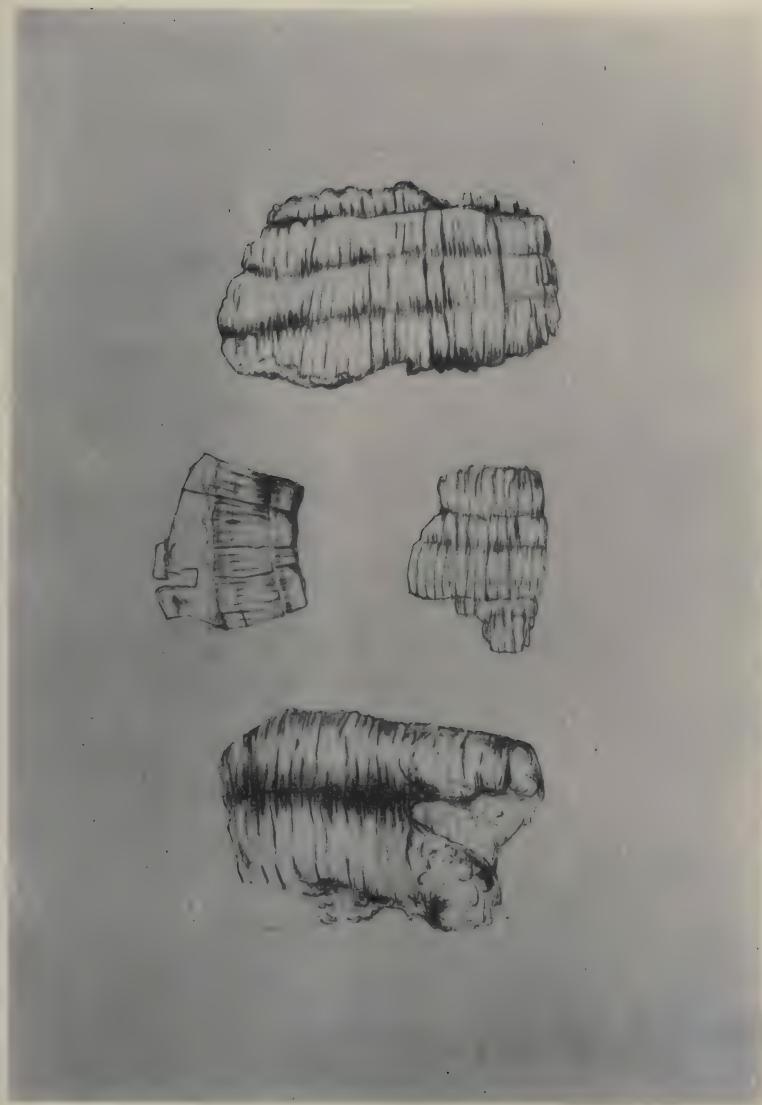


PLATE III.



THE FELSPAR (PROBABLY ORTHOCLASE) ALTERED INTO THE LARGE AGGREGATES OF KAOLINTOID.

× 200.

PLATE IV.



1. THE BLEACHED BIOTITE ALTER-
ED ALMOST COMPLETELY INTO
SCALY-GRANULAR KAOLINITOIDS.

× 240.



2. THE ORTHOCLASE IN WHICH
THE FORMATION OF KAO-
LINITOIDS IS BEGINNING.

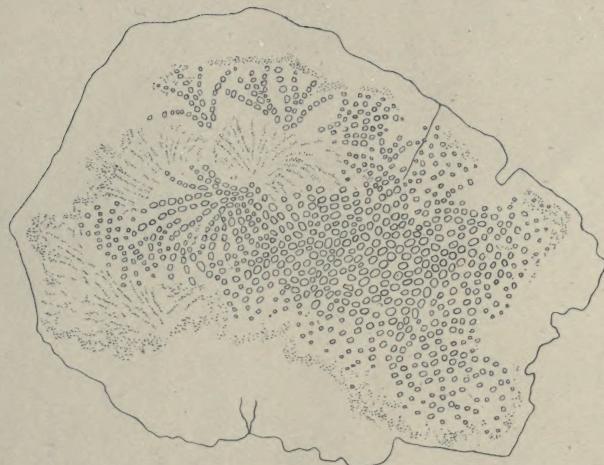
× 150.



3. THE DETACHED FLAKES AND AGGREGATES OF KAOLINITOIDS
MOST FREQUENTLY FOUND.

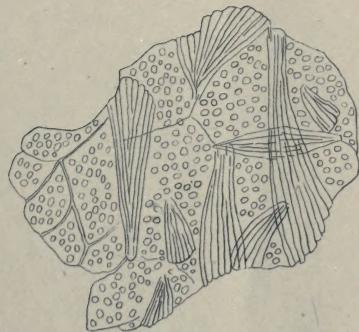
× 400.

PLATE V.



1. THE ALTERED BIOTITE, ON WHICH THE FORMATION OF
NONTRONITE IS BEGINNING.

× 150.

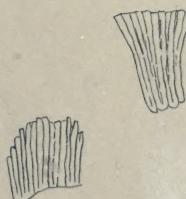


2. THE ALTERED BIOTITE PARTIAL-
LY COVERED WITH
THE BUNDLES OF NONTRONITE.

× 240.

3. THE DETATCHED
AGGREGATES OF
NONTRONITE.

× 240.



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